

AIR COMMAND AND STAFF COLLEGE

AIR UNIVERSITY

ENERGY INDEPENDENCE: CAUGHT BEHIND THE POWER CURVE

by

John D. Hess, Maj, USAF

A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

Advisor: Dr. Donald A. MacCuish

Maxwell Air Force Base, Alabama

April 2010

Abstract

The world's oil reserve is a finite resource which is rapidly being depleted; inevitably we will run out. It is the United States Government's fundamental responsibility to ensure we are prepared to face an oil-constrained, and eventually, an oil-free world. Currently, the US imports 2/3 of its oil from other nations, many of which are unstable and openly hostile to us. This leaves the US vulnerable to the whims of these nations and their leaders. To eliminate this threat, the US needs to commit sufficient resources to the development of technologies which are sustainable and will allow us to reduce and eventually eliminate the need for petroleum. The sooner we begin developing alternatives to oil, the less costly and painful it will be. This paper suggests that we simultaneously undertake a two prong approach, one that focuses on the near term activities which can be implemented in the 5-10 year timeframe and the second looks at technologies which may be implemented in the next 15-30 years.

Introduction

Oil is the lifeblood of the industrial world. It is the single greatest contributor to the advancement of civilizations and the source of great power and wealth. On the other hand, it is a cause of war, corruption, and the biggest contributor to modern day environmental degradation. Oil is easy to transport and manipulate, it has a tremendous variety of applications and, up to this point, it has been abundant, cheap, and easily attainable—this is about to change—the age of oil is ending. The world's oil reserve is a finite resource which is rapidly being depleted. It is the United States Government's fundamental responsibility to ensure we are prepared to face an oil-constrained, and eventually, an oil-free world.

The industrialization of the United States has led to its unprecedented prosperity and world dominance. It has also led to its addiction to oil. Our thirst for oil has steadily increased and greatly exceeded our production capacity. This deficit has created a dependence on foreign oil which poses a serious risk to the national security of the United States. It gives the oil producing nations the ability to manipulate our actions, dictate terms, and even the ability to decimate our economy. As this resource becomes increasingly scarce, prices will skyrocket and friction will develop between the oil import nations. How we survive this friction and transition to new technologies will depend on how well we prepared for the evolution.

Security Implications

The greatest threat to the United States, with respect to energy security, is our dependence on foreign oil. Our demand for oil has outpaced our production ability for the past six decades. Currently, the US imports 2/3 of the oil it consumes.¹ This leaves us extremely vulnerable to the whims of the oil producing nations, many of which are unstable and overtly

Energy Independence
John Hess

anti-American. Oil is not just another commodity sold on the open market, it is vital to our way of life; 97% of our transportation system relies on it,² our industrial base and economy depend on it, and ultimately, our ability to defend ourselves is determined by sufficient access to oil. The petroleum market is far from being an open, free trade market; rather it is largely controlled by the Organization of the Petroleum Exporting Countries (OPEC). OPEC is an intergovernmental organization made up of 13 oil producing nations and has control over 2/3 of the world's oil reserves and 1/3 of the oil production.³ Due to their stranglehold on this strategic resource, the cartel wields tremendous power over the oil import nations and they have demonstrated a willingness to use this power. For example, when the US agreed to re-supply the Israeli military during the Yom Kippur War, OPEC decided to use oil as a weapon and punished the US by initiating an oil embargo. The embargo only lasted from October 1973 until March 1974 but it had many long lasting impacts on our economy and our way of life. Likewise, the second and third order effects were felt around the world. During this period, the US imported less than half of the oil it consumed.⁴ If this were to happen today, the devastation would be much greater to the United States and the rest of the World due to our increased reliance on foreign oil and the globalization of world markets and economies.

From an enemy's perspective, our massive industrial production capability is a strategic center of gravity (COG) and would be of great concern for them. This COG is extensive and diverse; it is logical that the enemy would attempt to neutralize or diminish it before the initiation of hostilities. Conducting a critical factors analysis on this COG would inevitably lead them to realize that fossil fuels are a key requirement and vulnerability to our war machine. They would not need to bomb our factories or iron and aluminum mines or supply depots or rail yards or tank and aircraft production lines or even our military bases—they only have to disrupt our oil supply.

Energy Independence
John Hess

They could take out the oil tankers and/or their loading docks and a few pipelines and annihilate our production capability. They never have to set foot on US soil. This is a gross oversimplification of the task, but the point remains that oil dependency is a strategic vulnerability.

The United States is not the only major importer of petroleum products. Developing nations, such as China and India are becoming more industrialized and their energy demands are rapidly increasing. As their industrial base and economy matures, their need for oil will approach or surpass that of the United States. The annual increase in oil consumption for developed nations averages one to two percent, whereas the increase in developing countries is typically five to ten percent or greater per year.⁵ The sum of these increases is estimated to increase the world's oil demand by 50% by the year 2025.⁶ Given China's and India's massive populations, over 1 billion people each, their need for oil will continue to significantly increase for many decades. In the next 5-15 years this will seriously strain the global oil production system. Beyond that, it will stress the system to such a degree that conflict may result. When the demand for oil surpasses the world's production capability, nations are likely to make exclusive pacts with oil producing nations to secure their interests or they will go to war to obtain the strategic reserves. This will result in less oil available to the remainder of the world and could cause a global destabilization. Even if the United States' petroleum needs are met, the devastating effects on the rest of the world will jeopardize our security and greatly impact our intertwined economy.

To further compound the issue of increased oil consumption, the global oil reserves are finite and diminishing. The production or yield of an oil field grows until it reaches its peak production when roughly half of the oil has been extracted. After it has reached its peak, production declines until it is no longer economical to extract oil from that field. The rate at

Energy Independence John Hess

which new reserves are being discovered is rapidly declining even though an unprecedented effort is being invested in finding and exploiting them. For years there has been much speculation on when the world oil production will peak; a group of scientists and petroleum experts conducted a study for the Energy Watch Group and they concluded that it already occurred in 2006⁷. Others had a more optimistic view and believe it happened in early 2008.⁸ Regardless of when it peaked, the oil supply is limited and dwindling and the demand is rapidly increasing. When the sum of the world's oil production cannot meet the world's demands, prices will skyrocket and the world will become a more dangerous place.

The Way Ahead

Given the threats to national security caused by our dependency on foreign oil, the United States should take an aggressive approach to eliminate the threats and mitigate the impact to our way of life. A national security strategy (NSS) should be developed that leads us not only to energy independence, but ultimately leads us to a sustainable energy source independent of fossil fuels. The NSS should take a dual approach: the first branch should be a strategy for the near term—5-10 years. This strategy should be designed to alleviate the immediate threats caused by our energy dependence. This approach will catch the low hanging fruit and capitalize on efficiencies, cutbacks, and the exploitation of current technologies and resources to eliminate the need for oil importation. Due to the near-term necessity this track should seek and implement a wide variety of technologies and potential oil reducing methods to achieve this goal. In conjunction with these activities, the second branch should be initiated. This branch should focus on the long term—15-30 years and develop new technologies which are sustainable and environmentally friendly. The conclusion of this activity will result in the ability to conduct our

Energy Independence John Hess

daily lives without the use of petroleum (i.e. for transportation of goods or people, or for environmental control such as heating, cooling, and electricity).

Petroleum is also used in many of the products we use in our daily lives, such as plastics, acrylics, rubber, lubricants, solvents, adhesives, and countless other products. Most of these products are extremely durable, but have a short useful lifespan. After the products usefulness has expired, it frequently finds its way to a landfill where it will remain for thousands of years. Future technologies should also focus on recycling and eliminating such products. They should be replaced with biodegradable, environmentally friendly alternatives.

To achieve these lofty goals, the government should unleash the full force of its instruments of power (IOP). The magnitude of this effort will require full cooperation and support of the United States Government. A study conducted on the consequences of US oil dependency concluded that diplomacy has limited leverage to achieve energy security objectives through foreign actions.⁹ Since the diplomats are unable to coerce the oil producing nations, they should focus on soliciting support from the oil import nations. All oil import nations have the same energy security concerns as the United States and will be affected to a greater or lesser extent when the supply runs out. The diplomats should work to achieve a coalition of nations to aggressively develop technologies to wean us off fossil fuels. To avoid redundancies and duplication of research and development efforts, this coalition would pool resources to develop think tanks and cooperate with the research and development efforts.

The Information IOP is the key to achieving these goals. A global information campaign should be initiated to create an international movement for oil independence. An active movement will generate momentum and support for the “cause” and will pay dividends when the substantial bills require payment and sacrifices made. There are currently many minor efforts

Energy Independence
John Hess

which indirectly support this cause; most notably are the environmental movements such as recycling, pollution control, and global warming. These existing efforts need to be consolidated, given a new image, and revitalized.

The Military IOP will play an unconventional but not unprecedented role in this endeavor. Its role will be similar to its role during the Manhattan Project and the Space Race. The NSS would flow down to the National Military Strategy (NMS) which will allow the military to provide the leadership and structure for advancing future technologies. They can use their acquisition and contract management expertise as well as their substantial budget to engage industry in support of the NMS objectives.

The Economic IOP will be used to bolster support for the coalition as well as the movement. This is accomplished through the use of grants to universities and industry for innovative research and development projects. All grants must be for advancing the state-of-the-art for technologies which will lead to oil independence objectives. This IOP could also establish an X-Prize¹⁰ to foster an international competitive spirit and to entice innovators, entrepreneurs, industry, and academia.

To achieve these goals and alleviate this threat to national security will take a monumental effort and require mobilization of the United States Government, academia, and private industry. It will require commitment and sacrifice from the national leaders and the general population alike. The technologies required to enable this achievement have not been developed and will take tremendous financial backing and time—both of which are limited. Establishing a coalition of oil import nations will greatly assist this effort by sharing costs and workloads. It is imperative that the national leaders recognize these facts and immediately initiate this endeavor. A failure to begin this undertaking will greatly increase the overall costs

and the impact to the people. If we wait until we run out of oil, it will collapse the world's economy and wreak untold havoc throughout the world. Likewise, we will be riding a horse and buggy for twenty years until the technologies can be developed.

Current Technologies

Is it realistic to think that we will revert back to the horse and buggy days? The answer is no. We will not wake up one day and realize that we have run out of oil, but rather as the reserves are depleted, the cost to extract the oil greatly increases. The prices will continue to rise until potential financial gain or public outcry is sufficient to spur innovation or technology development.

In 2008, petroleum accounted for 37% of the total energy consumed in the US followed by natural gas at 24% and coal with 23%. Lagging behind is nuclear electric at 9% and all renewable energy sources combined to equal a paltry 7%.¹¹ The US consumes 19,498,000 barrels of oil per day. Of the nearly 20 million daily barrels, over 11.1 million barrels are imported daily (2008 figures). To eliminate the need for oil imports, we need to analyze the primary consumers of the petroleum.

Eighty four percent of the oil consumed in the US is converted into gasoline and diesel for the transportation of goods and people. The transportation sector is almost exclusively reliant on gas and diesel at 97%. The remainder utilizes natural gas, propane, and renewable resources. The reason gasoline and diesel are so appealing to the transportation sector is the specific energy of the fuels (i.e. the amount of energy extracted per weight and volume). These fuels are economical, relatively light weight, and easy to handle at normal temperatures and pressures.

Energy Independence
John Hess

Substitutions with similar characteristics to these fuels have been elusive if not incomprehensible.

Electric vehicles have made a modest revival with the recent increase in oil prices, but is this a viable substitution to petroleum? The electricity used to charge the batteries of these vehicles has to come from somewhere. Currently the vast majority of the electricity used in the US comes from burning coal or natural gas or from nuclear fission to create steam which turns turbines and generators. This system is heavily reliant on non-renewable resources and would have to be greatly expanded to accommodate the increased demand. Power generation and the electrical distribution grids are woefully lacking the capacity required for a transition to electrical vehicles.

Aside from the generation capacity and the long term sustainability of using electricity as the primary power source for transportation, there are many other drawbacks to this oil substitution. Most electric vehicles are only capable of traveling 100 to 200 miles on a single charge and take up to eight hours to recharge. This will require some lifestyle adjustments when compared to the average gasoline vehicle that can exceed 300 miles on a tank of gas and only takes a few minutes to refuel. The battery bank used to store the vehicle's electricity is also burdensome. To propel the vehicle at acceptable speeds requires a large, heavy battery bank. A fuel efficient gasoline vehicle can travel 100 to 200 miles on approximately 25 to 50 pounds of fuel, whereas an electric vehicle will require over 1000 pounds of batteries to travel the same distance. These batteries are very expensive and have a usable lifespan of two to three years depending on usage and maintenance. Furthermore, extreme temperatures, hot and cold, greatly diminish the battery's output and lifespan. Currently, lithium-ion batteries provide the best

power output to weight ratio, however, technological breakthroughs in ultra high output capacitors may supplant them as king.

When looking at viable substitutions for petroleum it is important to note that there are two major categories: renewable resources and non-renewable resources. Non-renewable resources may play a role in eliminating our need oil imports in the short-term phase, but since they are also limited in quantity, their supply will eventually run out as well. A truly viable long-term solution to our energy needs must be renewable, plentiful, environmentally friendly, and sustainable.

Non-Renewable Energy Sources

The major non-renewable energy sources are: oil (including its byproducts: gasoline, diesel, kerosene, heating oil, etc.), coal, nuclear energy, geothermal energy, and natural gas.

Fossil Fuels: Coal

Coal is a carbon based, combustible sedimentary rock formed from plant matter that was protected from bio-degradation and oxidization, typically by mud or acidic water. It is commonly found in thick bands or veins near the earth's surface. In the US, the primary usage of coal (97%) is for electrical power generation but it is also used in industry and for general heating of commercial and residential buildings. At current consumption rates, there is an estimated 147 year supply of known global coal reserves. The US has the largest reserves which account for 27% on the world's supply. At current extraction rates, the US reserves will last for 234 years.¹² Even with “clean coal” technologies, it remains a major pollutant and source of greenhouse gas emissions. It is possible to convert coal into other useful forms of energy, for

example, Germany converted coal into liquid fuel during WWII, but the process is very expensive.

Fossil Fuels: Natural Gas

Natural gas consists primarily of methane gas and is the product of decaying biological organisms. It is commonly found associated with other fossil fuels such as oil and coal. When oil is extracted from deep within the Earth and brought to normal atmospheric pressures, natural gas effervesces from the oil much like removing the lid of a bottle of soda. This gas requires processing to remove impurities such as ethane, propane, and butane. Although natural gas is a greenhouse gas, it burns approximately 30% cleaner than gasoline and 45% cleaner than coal. Natural gas is heavily utilized in industrial applications, power generation, and commercial and residential heating. The global natural gas reserves are estimated at 177 trillion cubic meters with Russia, Iran, and Qatar as the primary benefactors. They account for more than 57% of the world's reserves; all remaining countries have less than 5% each. According to the International Energy Outlook 2009 report, the global reserves will last for 63 years at current production rates. The US is the largest consumer of natural gas and has 3.8% of the global reserves.¹³ Due to limitations in recovering the gas, our production is not able to meet our current demand.

Nuclear Energy

Nuclear energy is created by the fission of molecules. Fission, meaning to split apart, is accomplished by striking the nucleus of an atom with a neutron to split it into multiple pieces. The split pieces in turn split other atoms and cause a chain reaction. When an atom is split, it releases tremendous amounts of energy. When this is accomplished in a controlled environment, such as a nuclear reactor, the energy can be harnessed and used to create electricity. When this is

Energy Independence John Hess

accomplished in an uncontrolled environment, the energy is released very rapidly and becomes a nuclear bomb like the ones used on Hiroshima and Nagasaki.

Although all atoms have this potential energy, radioactive substances such as uranium 235 is typically used for this process due to its relatively large size and the instability of the nucleus which simplifies the fission process. One pound of uranium can produce approximately the same amount of energy as burning 2.3 million pounds of coal.¹⁴ This makes nuclear energy very attractive, but the hazards associated with this form of energy are severe. In 1979 a stuck valve on a cooling line caused a partial nuclear core meltdown in one of the reactors on Pennsylvania's Three Mile Island. This incident effectively ended America's love affair with this new form of electrical power. That sentiment was solidified in 1986 when a meltdown in the Chernobyl nuclear power plant in Ukraine (then part of the Soviet Union). Other drawbacks to nuclear energy are the difficult uranium enrichment process and, more importantly, what to do with the radioactive spent fuel rods. The uranium waste poses a significant hazard to humans and the environment for tens of thousands of years.

Geothermal Energy

Geothermal energy is created by water flowing over hot magma beneath the Earth's crust and capturing the steam it produces to turn generators. This is only possible where the crust is thin due to plate tectonics; where the plates collide and force one plate beneath the other or where there is a rift caused by plate separation. The amount of energy extracted from the Earth using this process is so minute as compared to its overall thermal capacity that this could be used for millions of years. However, it is considered a non-renewable resource due to localized effects. Over saturation of an area can extract energy faster than it is replenished. Re-injecting the hot water (condensed steam) helps avoid this issue. This technology is likely to remain an

obscure energy source due to the limited areas where it can be produced; however with new developments in drilling and metallurgy, this may become more popular.

Renewable Energy Sources

Renewable energy has greater appeal because, by definition, they are sustainable resources and are typically more environmentally friendly. However, they are typically more sensitive to the environmental conditions of the particular regions in which the energy is developed. Solar energy, for example, is much more effective in the Southwest US than in the Northwest US due to the amount of cloud cover experienced throughout the year. The amount of solar radiation reaching the surface of the earth is also dependent on the inclination of the earth and the latitude of the collectors. The final and most significant drawback of solar energy is that it doesn't work at night.

Solar Energy

There are two basic methods of harnessing the energy of the sun to create electricity: direct and indirect approaches. The direct approach uses photovoltaic cells to convert the solar radiation into direct current (DC) electricity. This electricity could either be consumed immediately or stored for use at a later time. The indirect approach uses parabolic mirrors to direct and concentrate the solar radiation. This concentrated radiation is then used to create steam which drives a steam turbine to generate alternating current (AC) electricity.

Wind Energy

Harnessing the wind is an effective method of generating electricity and it is extremely environmentally friendly. The greatest complaint with this method is that of aesthetics. Its primary limitation is the availability of sufficient wind. Too little wind will not turn the

generator; too much wind will destroy it. Although modern generators have feathering blades that can be adjusted to increase or decrease the efficiency of the airfoils to ensure the generator does not over speed, there is no way to compensate for a lack of wind. It is this reason this method does not have wide spread usage.

Hydroelectric Energy

Water has long been used to generate electricity. Most industrial centers in the US were developed next to rivers that could be harnessed for hydroelectric power. When hydroelectric power is mentioned, most people think of a dam on a river to harness the potential energy of the water; however, that is not the only way to generate electricity with moving water. The waves and tides of the ocean can be used to change the potential energy of the water. Although these methods do not raise the water level a significant height, it makes up for it by moving massive amounts of water. Hundreds of thousands small generators could be used to create an endless supply electricity, day and night.

Waves can be funneled into a narrow channel which will increase the wave's height several times to create a greater potential energy. Likewise, a narrow opening of a bay could be used to funnel the water. Larger bays allow more water to flow through the opening with each change of tide and can generate more electricity. When pushed to the extreme, such as the Strait of Gibraltar leading to the Mediterranean Sea, a completely different phenomenon occurs. Due to the size of the Mediterranean Sea (970,000 square miles), a tremendous amount of water evaporates from the surface. This causes a near-continuous Eastward inflow of water to replace the evaporated water. As the water evaporates from the surface, the salinity at the surface increases which increases its density. The heavier (denser) water settles towards the bottom and collectively causes a westward movement of water at the lower depths.

The Gulf Stream is a strong ocean current that flows up the east coast of the US and circulates clockwise around the north Atlantic. This current regulates the climate in both North America and Europe by transporting massive amounts of warm water from the Caribbean. The current is most concentrated between the narrow gap between Florida and the Bahamas. The velocity is greatest near the surface and has a maximum flow of 5.6 miles per hour and an average rate of 4 miles per hour along the Eastern seaboard.¹⁵ In this region, the current is moving 30 million cubic meters of water per second, which is approximately 20 times greater than all freshwater rivers in the World combined. When the current reaches Newfoundland it is transporting an astounding 150 million cubic meters of water per second.¹⁶ If the energy of the Gulf Stream could be harnessed, it would be capable of meeting entire world's energy needs.

Biomass Energy

Biomass is another source of energy that has received tremendous attention and growth in recent years. Biomass is a broad category that spans from simply burning waste products, such as, burning scraps of wood at a paper mill to heat water, to genetic engineering to produce biogas and diesel. This section will focus on liquid fuels which could primarily be utilized in the transportation sector, but is also appropriate for industrial and residential heating or for power generation.

Biofuels are liquid fuels which are derived from renewable resources such as plants or animals. This technology has been around for a long time; the Ford Model T was the first vehicle to use it. Biogas is an alcohol based product typically made from ethanol. Other alcohols such as methanol, propanol and butanol are less common due to their lower specific energy. It is created by fermenting the sugars and starches contained in the biomass. Biodiesel

Energy Independence
John Hess

is made from vegetable oil and animal fats. This product can be used “as-is,” but typically contains additives to reduce the particulate matter and pollutants.

These fuels have greatly evolved in recent years as the demand has radically increased with higher oil prices. First generation ethanol was made from vegetables and seeds such as corn, sugarcane, soybean, sunflower, wheat, and many others. These sources were selected because of their ease of distillation and output quantity. This method of producing ethanol became highly criticized as food prices inflated.

According to the Department of Transportation, Americans drove over three trillion miles in 2007 in passenger cars and light trucks.¹⁷ Given the average vehicle gets 20.9 miles per gallon,¹⁸ we used over 154 billion gallons of fuel. Cornell University did a study and determined that an acre can produce 7,110 pounds of corn, which could be processed into 328 gallons of ethanol.¹⁹ Ethanol contains 75% of the energy gasoline has, therefore, it would take over 583 million acres of land or roughly ¼ the total area of the US to replace the petroleum consumed by automobiles. Since only 18% of the land is arable,²⁰ it would require half again as much arable land just to grow crops for fuel. Clearly this is not an acceptable solution.

Scrutiny over using food sources for fuel led to the development of the second generation ethanol processing which is less efficient, but it utilizes non-food sources. Second generation ethanol processing is capable of using almost any wood, grass, or plant as a source for ethanol. Although it eliminates the negative effects of using the consumable food supply, it is less efficient than the first generation methods and requires tremendous organic resources.

The latest bio technology is third generation which uses algae as the biomass and experiments have demonstrated this method is 30 times more efficient than using soybeans; however, these yields have not been demonstrated commercially yet. This method uses sunlight

and carbon dioxide from the air or other sources to grow the algae. One study by the Department of Energy claims that combining an algae farm with a catfish farm would create a symbiotic relationship beneficial to both.

“Using algae ponds to remove catfish litter from the catfish ponds at an accelerated rate would improve the yields of the catfish ponds dramatically. The algae ponds would also hyper-oxygenate the catfish pond water and reduce, or eliminate, unwanted algae blooms in the catfish ponds. Productivity from the catfish ponds could easily triple, and the revenues from the algae ponds would match those of the catfish ponds²¹”

Third generation biofuels have great potential as a petroleum substitute; the Department of Energy estimates it would require 15,000 square miles (an area roughly the size of Maryland) to replace all petroleum used in the US.²²

To put this into perspective, a city with 250,000 homes could be powered by a single 1,000 megawatt power plant. To generate 1,000 megawatts of electricity from the various renewable resources would require:²³

- 386 square miles of solar panels
- 6660 150kV wind mills with 20m blades
- 6216 square miles of corn for first generation ethanol
- 11,583 square miles of trees for second generation ethanol

Long Term Solutions

Biofuels and other renewable sources of energy can provide a short- to medium-term solution to our energy needs. They offer an environmentally friendly (or at least environmentally neutral) alternative to petroleum. This will allow the US to minimize the use of petroleum to those applications where there are no viable alternatives without requiring imports. These mid-term solutions are acceptable as a stopgap, but we need to work to a long-term solution to meet our energy needs. What technologies should we pursue that could meet an ever

Energy Independence John Hess

increasing demand? The characteristics of this new technology must not be restricted by meteorological conditions, time of day, or proximity to the sea or geological hotspots. It must be expandable and adaptable to a variety of applications, easy to manipulate and transport, environmentally friendly and completely sustainable.

This is a big order to fill. We currently consume many types of energy: electric, liquid fuels, gases (gaseous at normal atmospheric temperatures and pressures), solids, and radioactive. It may not be reasonable to assume a single new technology will be able to assume all forms currently used; however, if there is a plentiful energy source, whatever form it comes in, it can be manipulated to serve all our needs or our machines will be altered to accommodate that power source. For example, if the new technology comes in the form of electricity, it could be converted onto a gas through electrolysis (the separation of water into elemental hydrogen and oxygen) which could be utilized in the transportation industry. Alternately, or in addition to, our machinery can be adapted to the energy source, such as, developing large capacitor banks on automobiles to rapidly accept an electrical recharge. The key is to just develop a plentiful energy source, everything else will adapt.

There are some concepts and theories which may fit these requirements, but they require significant research and development to take them from theories to concepts to experiments, to prototypes to implementation. Most advanced concepts focus on electrical energy due to the wide variety of methods that can create it, as well as, its near-universal applicability.

Space-based power generation is not a new concept—it has powered satellites since the beginning of the space age—but it has never been applied to terrestrial applications. There are multiple methods of generating power in orbit; common philosophies include: solar panel arrays which convert solar radiation into direct current; heat engines which utilize the dramatic

Energy Independence John Hess

temperature differences experienced in the vacuum of space; and electromagnetic tethers which generate electricity by orbiting long cables through the Earth's magnetic field. Solar power generation from an orbiting solar arrays have tremendous advantages over their terrestrial counterparts. The primary benefits include increased efficiency and continuous generation capability. The increased efficiency is due to the absence of atmospheric disturbances. The atmosphere dissipates or reflects approximately half of the solar radiation before it reaches the surface of the Earth. Another advantage of the orbital array is its ability to provide continuous or near-continuous power generation, depending on its orbit. For example, a solar array placed in geosynchronous orbit is always "in sight" of the intended ground station, but there are increased launch costs associated with that orbit and geosynchronous orbital slots are highly coveted for communication satellites. Lower orbits have reduced launch costs, but they require additional arrays and require complicated hand off processes. In order to transmit the power from orbital tethers, heat engines, and solar arrays, the energy must be converted into a high frequency beam, such as microwave, and beamed to Earth. The higher frequencies penetrate the Earth's atmosphere with less attenuation. Beaming megawatts of power from space reduces some of the efficiency gained and it is not without its critics. There is significant resistance of this approach due to human safety and the potential or perception for this system to be used as an offensive weapon.

The "Holy Grail" of future power generation concepts is fusion power. Unlike traditional fission nuclear power where heavy, unstable radioactive atoms are split apart, fusion combines light atoms such as hydrogen isotopes to create the heavier atom helium. When the atoms' nuclei combine, excess neutrons are released which also releases a tremendous amount of energy. Any atoms lighter than iron could potentially be used as a fuel source; however, larger atoms and

Energy Independence John Hess

stable atoms require significantly more energy to initiate the process. Isotopes, on the other hand, have unstable nuclei and are much easier to manipulate. The best fuel source candidate for fusion power is hydrogen. Deuterium (or heavy hydrogen) and Tritium (heavy-heavy hydrogen) are naturally occurring isotopes of hydrogen.²⁴ Deuterium is commonly found in ordinary fresh water as well as the oceans at a rate of 1:6500 atoms or 154 parts per million.²⁵ Tritium is a relatively rare isotope of hydrogen also found in water; however, it can easily be produced by injecting the excess neutron (which is a byproduct created during the fusion process) into the abundant light metal Lithium. This cyclic process has the potential of satisfying the entire world's energy needs from a virtually inexhaustible fuel source. It is estimated that 10 trillion tons of Deuterium exists in surface water on Earth. Lithium, which is only one method of producing Tritium, is available in land deposits which could last thousands of years or it could also be extracted from the sea.²⁶ One study concluded that at 1995 global energy consumption levels, the Deuterium supply would last 150 billion years; Lithium from land deposits would last 3000 years; and Lithium from the ocean would last another 60 million years.²⁷

When this technology moves from experimentation to application, the benefits will be astounding. For example, to generate 1,000 megawatts of electricity using coal as the fuel source, it requires 18 million pounds of coal and releases 60 million pounds of CO₂ into the atmosphere and 2 million pounds of solid waste.²⁸ Alternately, to produce 1,000 megawatts of electricity with fusion, it only requires 1 pound of Deuterium and 3 pounds of Lithium (which creates 1.5 lbs of Tritium) and releases 4 pounds of Helium into the atmosphere.²⁹ Helium is an inert gas; it does not cause greenhouse or other harmful atmospheric effects. This process will eliminate the need for fossil fuels along with our primary source of air pollution. Traditional nuclear fission power plants are fraught with potential dangers, such as, storing large quantities

of radioactive material, large scale contamination, and used as a front for developing nuclear weapons. Fusion power plants will not have any of these dangers. It does not use highly radioactive materials nor is there a potential for contaminating large areas. If a fusion reactor had an incident or meltdown, the hydrogen plasma contained within the reactor would dissipate into the atmosphere or surrounding walls and cool. When the reactor is breached, a drop in temperature or pressure would stop the fusion process. The only danger associated with a fusion reactor meltdown is from exposure to the superheated gases, excess neutrons within the reactor and from the radioactivity of the inside of the reactor. These dangers are highly localized and not a threat to the general population. As soon as the gases and neutrons cool, they no longer pose a threat. Careful selection of material used to construct the reactor will mitigate the radioactivity of the inside of the reactor. Vanadium and silicon-carbide are examples of materials that can withstand neutron bombardment without becoming highly radioactive³⁰.

Although there are many benefits of using fusion for generating electricity, the greatest benefit is the wide availability of the fuel sources. This will relieve all tension caused by energy needs and the uneven distribution of petroleum resources. Without the competition for limited petroleum resources, regional and global stability can ensue. The power and influence wielded by oil-producing nations will rapidly diminish into obscurity and national interests in the Middle East will cease to exist. This will allow complete troop withdrawal and eliminate the justification for extremist movements.

Conclusion

Fusion power generation has the potential for meeting the world's energy needs for tens of millions of years. The fusion power generation process does not have harmful side effects or

damage the environment. The resources (or fuel) required to generate the electricity is naturally occurring hydrogen isotopes commonly found in ordinary water which is readily available to all nations. This will eliminate the competition caused by unequal distribution of scarce petroleum resources. The oil producing nations will no longer wield the power to control the world's economies and hold the US at risk.

However, there is much work to be done before fusion power becomes commercially available. In 1970 the Joint European Torus (JET) project was initiated to demonstrate the plausibility of fusion power generation. The facility was officially opened in 1984 and it achieved the world's first controlled release of fusion power in 1991. Future demonstrations continued to increase the efficiency of the reactor; in 1997 the JET produced 65% of the input energy.³¹

Progress towards advancing this technology has been painfully slow. This is primarily due to the limited political foresight and lukewarm financial commitment. The reactors needed for research and development are very expensive and must compete with other pressing needs in a fiscally constrained budget. To share the cost burden, the US has joined the European Union, India, Japan, China, Russia, and South Korea³² to build the next generation fusion reactor, named the International Thermonuclear Experimental Reactor (ITER). Unlike the JET, which was not designed to produce more power than it consumed, the ITER is expected to produce 5-10 times more energy than it consumes.³³ Currently being built in South France, the experimental project is the largest scientific project ever initiated and is expected to cost 10 billion euros to build and operate over the 30 year life of the program. The ITER follow-on project is a demonstration power plant appropriately called DEMO (DEMONstration Power Plant). It is being designed to

Energy Independence
John Hess

produce 2 gigawatts of sustained power. Engineering designs are to be completed in 2024 and initial construction complete in 2033, upgrades and improvements completed in 2040.³⁴

If the ITER and DEMO experiments succeed as planned, we could be weaned of fossil fuels and totally on fusion power by the turn of the 22nd century. That is a long time to be dependent on foreign oil and its associated threat to national security. Furthermore, research and development, experimentation, testing, changes to infrastructure, construction, budget constraints, politics, and the open market all play their part in extending this time line—of these, political commitment will cause the greatest damage or do the greatest good. With the \$60 billion given to AIG during the 2009 bailout, ITER, DEMO, and multiple fusion power plants could have been fully funded. This would have created jobs and expedited our departure from oil. The longer we delay this departure, the greater the danger becomes. We need to actively and aggressively embrace this change—to do so will take the will of the people and insightful, shrewd political leadership capable of seeing beyond their next election.

¹ CIA World Factbook, Updated 30 September 2009. <https://www.cia.gov/library/publications/the-world-factbook/geos/us.html>

² Korin, Anne, Rising Oil Prices, Declining National Security, Testimony to the House Committee on Foreign Affairs, 22 May 2008

³ United States Department of Energy, Energy Information Administration. <http://www.eia.doe.gov/> downloaded 14 October 2009

⁴ Korin, p. 3

⁵ Deutch, John, James R. Schlesinger, and David G. Victor. *National Security Consequences of US Oil Dependency, Independent Task Force Report*. p. 369

⁶ Hirsch, Robert L. *The Inevitable Peaking of World Oil Production*. p. 400

⁷ Crude Oil: The Supply Outlook, Report to the Energy Watch Group, October 2007, p. 16

⁸ Association for the Study of Peak Oil and Gas, ASPO 2009 International Peak Oil Conference 11-13 October 2009, <http://www.aspo-usa.org/2009denver/index.cfm>

⁹ Deutch, p. 370

Energy Independence

John Hess

¹⁰ The mission of the X-Prize Foundation is to bring about radical breakthroughs for the benefit of humanity.
<http://www.xprize.org/>

¹¹ US Energy Information Administration, "Annual Energy Review 2008" Tables 1.3, 2.1b-2.1f. 13 July 2009.

¹² US Department of Energy, Energy Information Administration, "Coal Reserves Current and Back Issues," 2008
<http://www.eia.doe.gov/cneaf/coal/reserves/reserves.html>

¹³ US Department of Energy, Energy Information Administration, "International Energy Outlook 2009," Chapter 3, Natural Gas, 2009 http://www.eia.doe.gov/oiaf/ieo/pdf/nat_gas.pdf

¹⁴ One pound of Uranium-235 contains approximately 3.7×10^{13} Joules; one pound of coal contains 1.6×10^7 Joules. See also: Department of Physics, Syracuse University.

http://physics.syr.edu/courses/modules/ENERGY/ENERGY_POLICY/tables.html

¹⁵ US National Oceanic and Atmospheric Administration, National Ocean Service, "Ocean Facts,"
<http://oceanservice.noaa.gov/facts/gulfstreamspeed.html>

¹⁶ Joanna Gyory, Arthur J. Mariano, Edward H. Ryan. "The Gulf Stream." Ocean Surface Currents. 2008
<http://oceancurrents.rsmas.miami.edu/atlantic/gulf-stream.html>.

¹⁷ US Department of Energy, "Transportation Energy Data Book" Edition 28. published by Oak Ridge National Laboratory (ORNL) under contract with U.S Department of Energy, Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Program and the Hydrogen, Fuel Cells, and Infrastructure Technologies Program. 30 June 2009.

¹⁸ Calculated by 54% of the vehicles are passenger cars which average 24.0 mpg and 46% light trucks which average 17.3 mpg. Statistical information gathered from: US Environmental Protection Agency, Office of Transportation and Air Quality, "Emission Facts: Average Annual Emissions and Fuel Consumption for Gasoline-Fueled Passenger Cars and Light Trucks" August 2005. See also: US Department of Energy, "Transportation Energy Data Book" Edition 28. 30 June 2009.

¹⁹ Pimentel, David, "Limits of Biomass Utilization" Encyclopedia of Physical Science and Technology (Third Edition) Pages 159-171 2004.

²⁰ CIA World Factbook, 30 September 2009.

²¹ Putt, Ron, "Algae as a Biodiesel Feedstock: A Feasibility Assessment" Center for Microfibrous Materials Manufacturing, Department of Chemical Engineering, Auburn University, 20 November 2007.

²² Planktos Science, Biofuels Division, "Ocean Biofuel Today?" 2008 <http://www.planktos-science.com/Biofuels.html> downloaded 24 Feb 2010.

²³ J. Ongena and G. Van Oost. "Energy for Future Centuries" Laboratorium voor Plasmafysica– Laboratoire de Physique des Plasmas Koninklijke Militaire School– Ecole Royale Militaire; Laboratorium voor Natuurkunde, Universiteit Gent; (both in Belgium). pp. Section III.B. and Table IV. <http://www.fusie-energie.nl/artikelen/ongena.pdf>.

²⁴ Deuterium is also known as heavy hydrogen because it contains an additional neutron; Tritium or heavy heavy hydrogen, contains two neutrons.

²⁵ US Department of Energy, Office of Science, Fusion Energy Sciences Program, "What is Fusion?"
<http://www.ofes.fusion.doe.gov/whatisfusion.shtml>, downloaded 24 Feb 2010.

²⁶ US Department of Energy, Princeton Plasma Physics Laboratory. "Advantages of Fusion,"
<http://www.pppl.gov/fusionadvantages.cfm>, downloaded 24 Feb 2010.

²⁷ Ongena and Oost, Table VI

²⁸ At first glance, the figures may seem misleading due to a larger output than input. However, a closer look at the molecular changes that occur during the combustion process will explain the perceived incongruence. Coal is primarily made up of carbon. During the combustion process, the carbon atom (elemental weight of 12.011 atomic mass units) is combined with two oxygen atoms (elemental weight of 15.999 amu). The remainder of the weight increase is due to nitrogen (elemental weight of 14.007 amu) and other gases in the air, as well as, impurities in the coal.

Energy Independence

John Hess

²⁹ US Department of Energy, Princeton Plasma Physics Laboratory. "Advantages of Fusion." See also: US Environmental Protection Agency, Office of Solid Waste and Emergency Response, "Report to Congress on Wastes from the Combustion of Fossil Fuels" March 1999.

http://www.epa.gov/osw/nonhaz/industrial/special/fossil/volume_1.pdf

³⁰ Robert F. Heeter, et al.. "Environmental Characteristics of Fusion as a Future Energy Source," Conventional Fusion FAQ Section 2/11 (Energy) Part 2/5 (Environmental). 29 Sept 1994.

³¹ EFDA JET, Culham Science Centre, Abingdon, Oxfordshire, OX14 3DB, United Kingdom

<http://www.jet.efda.org/>

³² Canada was originally a full partner, but has since pulled out due to a lack of government funding.

³³ Output is expected to produce and sustain 500 MW for 1000 seconds.

³⁴ ITER Organization Headquarters, St. Paul-lez-Durance Cedex, France. <http://www.iter.org>